Spatial and Seasonal Precipitation Distribution in Southwest Idaho

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ABSTRACT

The Northwest Watershed Research Center operates a precipitation gage network on the Reynolds Creek Experimental Watershed in southwest Idaho. Analysis of the 16-yr record from this network shows that the average annual precipitation ranged from 250 mm on the low elevation (1100 m) areas of the watershed to 1100 mm on the high elevation (2160 m) areas. At all sites, the maximum average monthly precipitation was during December and January and the minimum was during July. There was a linear relationship between summer (May through October) precipitation and elevation and winter (November through April) precipitation and elevation. July and August storm durations averaged about 3.6 hr at both the low and high elevations. December and January storms averaged 5.2 hr duration at the low elevations and 8.6 hr at the high elevations. The average interval between storms during July and August was 7.7 days at the low elevation site and 6.6 days at the high elevation site. The average interval between storms during December and January was 2.9 days at the low elevations and 1.7 days at the high elevations. At all elevations, the interval between storms was longer for the two summer months than for the two winter months. The 2-yr 6-hr precipitation at the low elevations was 20 mm, which was the same as listed in the Precipitation Frequency Atlas. The 2-yr 6-hr precipitation at the high elevations was about 40 mm, or twice the value shown in the atlas.

These analyses show precipitation characteristics of a mountainous area from a dense precipitation gage network and provide data for hydrologic modeling and resource inventory evaluation. The results also show precipitation-elevation relationships and durations for representative summer and winter storms that were previously not available from weather records. For erosion studies where an index of storm intensity is needed, the 2-yr 6-hr data also provide much greater detail than previously available.

KEYWORDS: Precipitation, hydrology, climatology, precipitation, intensity, Idaho, rainfall, snowfall, rain gage, precipitation duration, interval between storms, Pacific Northwest.

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SPATIAL AND SEASONAL PRECIPITATION DISTRIBUTION IN SOUTHWEST IDAHO

By C. L. Hanson, R. P. Morris, R. L. Engleman, D. L. Coon, and C. W. Johnson[1]

INTRODUCTION

Precipitation amounts and their spatial and seasonal variations are basic to all hydrologic and to many natural resource studies. The USDA-SEA-AR, Northwest Watershed Research Center operates a precipitation gage network as an integral part of the hydrologic studies on the Reynolds Creek Experimental Watershed (fig. 1). The experimental area is a 234-km^2 watershed located in the Owyhee Mountains of southwest Idaho (*11*).[2] The lowest elevation on the watershed is 1097 m; the eastern boundary rises to about 1525 m; the western to 1830 m; and the southern to a peak of 2195 m. Reynolds Creek is a north-flowing tributary of the Snake River.

Idaho Precipitation

Located some 480 km from the Pacific Ocean, Idaho's major moisture source is maritime air from prevailing westerly winds. The westerly winds are able to carry more moisture into northern Idaho through the Columbia River Gorge than into southern Idaho, because of the mountain ranges to the west. During the summer, some moisture is brought in from the Gulf of Mexico at high levels, which produces thunderstorms, particularly in the eastern part of the State.

Precipitation ranges widely in Idaho, with large areas of the northeastern valleys, Snake River plains, and southwestern valleys, such as lower Reynolds Creek, receiving less than 250 mm annually and some mountainous areas receiving over 1500 mm annually (*1*, *6*, *10*).

Seasonal precipitation distributions show a winter maximum and summer minimum in the northern and southwestern portions of the State, and a summer maximum and winter minimum in the eastern part of the State.

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[2]Italic numbers in parentheses refer to Literature Cited, p. 14.

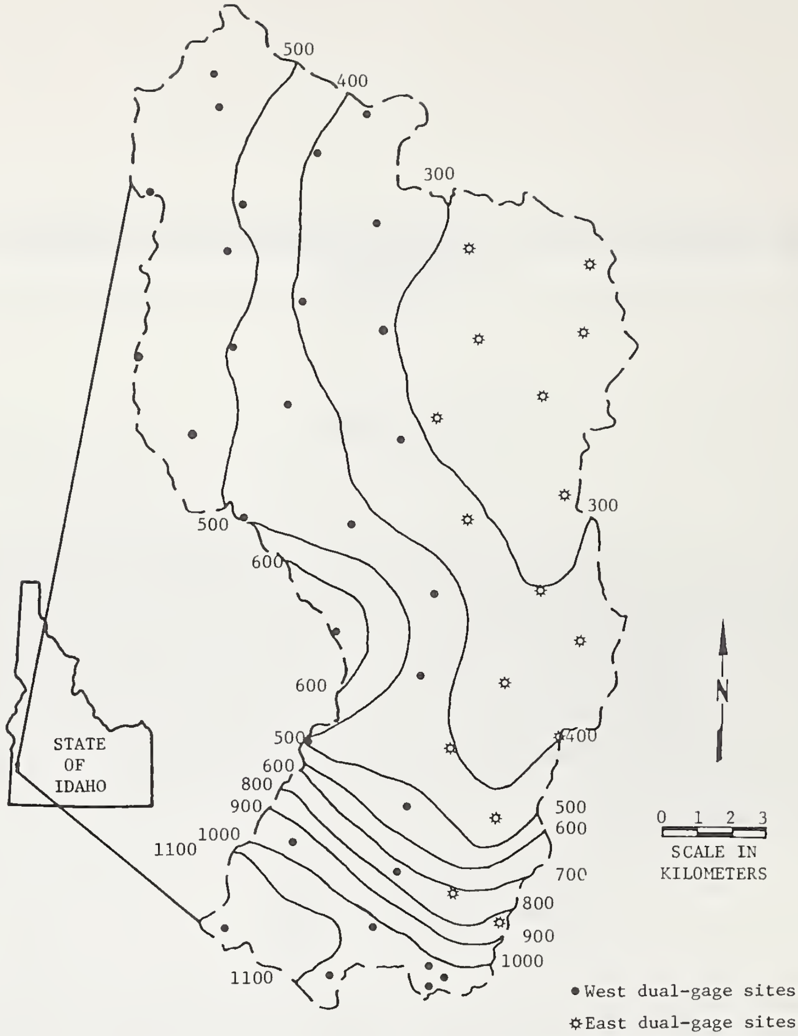

Figure 1.--Isohyetal map with the locations of the precipitation measuring sites, Reynolds Creek Experimental Watershed. (Small map indicates location of watershed in southwest Idaho.) Numbers indicate millimeters of annual precipitation.

Reynolds Creek Precipitation Gage Network

The original gage network, established in 1960-61, consisted of 83 unshielded recording gages (fig. 2A). Most of the precipitation that falls on the watershed is snow, and the network of single, unshielded gages was not measuring snow precipitation adequately. Therefore, during 1967-68, the network was converted to 46 dual-gage installations, one unshielded and one shielded gage (fig. 2B). Hamon (*3*) described each gage location and provided maps showing the original and the dual-gage network sites. Table 1 lists the 46 dual-gage sites by site location number and dates of operation. After a thorough analysis of records to determine which gage sites best represented different areas of the watershed, the dual-gage network was further reduced, during 1976-77, to 19 sites (table 1), which are still in use.

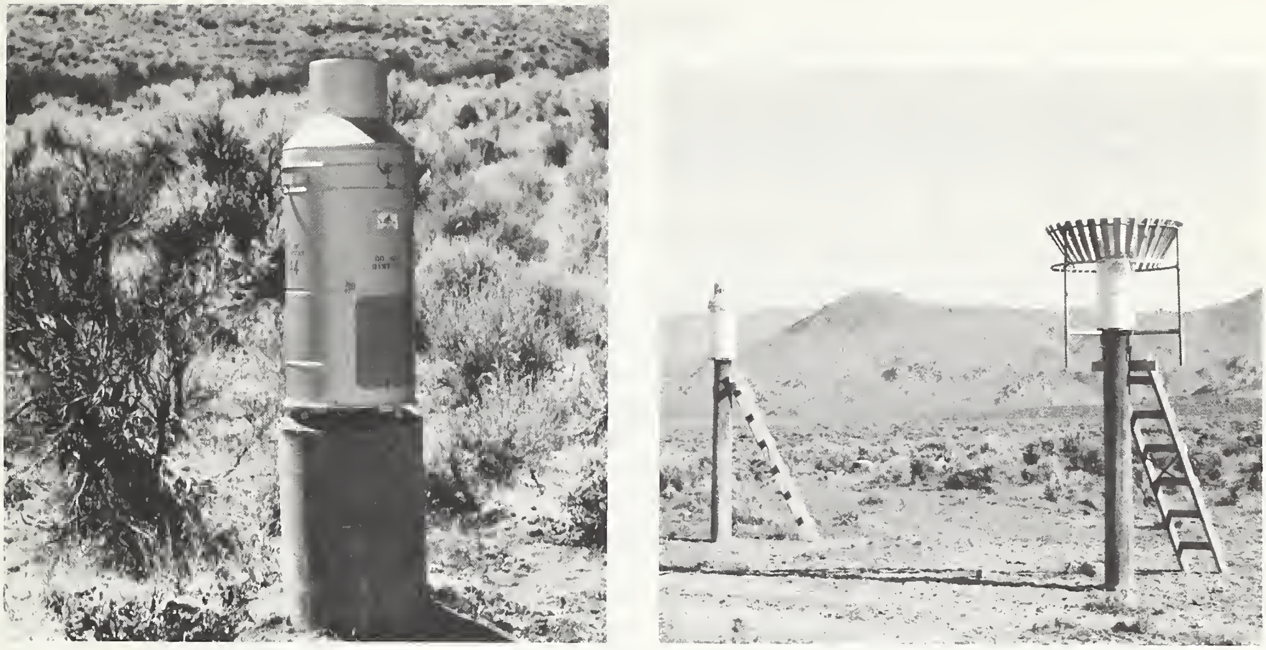

Figure 2.--Typical precipitation sites: A, Unshielded; B, dual-gage.

Table 1.--*Length of record by dual-gage precipitation site*

Site No.	Record length	Site No.	Record length
	Years		*Years*
012X29	1962-76	095X10[1]	1962-77
015X95	1962-76	097X00	1965-75
023X01[1]	1962-77	106X36	1968-75
024X76	1962-76	108X04	1965-75
031X48	1968-75	114X19[1]	1962-77
033X76	1962-77	116X91[1]	1962-77
043X41	1965-75	119X03	1965-75
045X04	1965-75	124X84[1]	1962-77
047X52	1965-75	126X97[1]	1962-77
049X61	1965-75	127x07	1962-77
053X93[1]	1968-77	128X87[1]	1965-75
054X23	1965-75	144X62[1]	1962-77
055X88	1965-75	145X37	1965-75
057X96[1]	1962-77	147X35[1]	1962-77
059X71	1965-75	155X07[1]	1962-77
061X25	1965-75	156X68	1965-75
072X67	1965-75	163X20[1]	1962-77
074X12	1968-75	165X02	1970-75
075X89	1965-75	166X94	1968-75
076X59[1]	1962-77	167x07[1]	1962-77
078X14	1965-75	174X17[1]	1962-77
083X92	1965-75	176X07[1]	1962-77
088X65[1]	1962-77	176X14[1]	1971-77

[1]Indicates that the site was continued after Dec. 31, 1977.

PROCEDURES

The continuous precipitation record was computed for the 46 dual-gage sites, using the following equation:

$$ln \frac{U}{A} = 1.8 \; ln \frac{U}{S} \qquad (1)$$

where, A is the computed precipitation, U is the unshielded precipitation, and S is the shielded precipitation (*4*, *5*). Actual precipitation prior to 1968 was computed for this study using unshielded-gage data from sites that were at or near dual-gage sites. Comparable dual-gage and unshielded precipitation values were determined by regression techniques that incorporated seasonal (summer and winter) and elevation parameters. This procedure was used to develop a record for the years prior to 1968 at 39 dual-gage sites. Table 1 shows 18 sites with a 16-yr record (1962-77); 3 sites with a 15-yr record (1962-76); 18 sites with an 11-yr record (1965-75); and 7 sites with a 10-yr record or less. All of the analyses in this study were based on the above precipitation records. The other data from the original network sites not listed in table 1 were not used.

In this publication, "storm" was defined as a precipitation period separated from preceding and succeeding precipitation by more than 4 hr. Summer storms were classified as occurring from May through October, inclusive; and winter storms as occurring from November through April. In these studies of storm duration and intervals between storms, December and January data were used to represent winter storms, and July and August data were used to represent summer storms. The shortest storm duration period considered was 5 min. The interval between storms was the time from the end of a storm that started during either December or January and July and August until the beginning of the next storm. The next storm may have started during the month studied, but if there was a considerable span of time between storms, the time could have included days from successive months.

RESULTS

Annual and Monthly Precipitation

The average annual precipitation on the Reynolds Creek Experimental Watershed ranged from about 250 mm on the low elevation (1100 m) in the northeastern area to about 1100 mm at the high elevation (2160 m) in the southwestern areas of the watershed (fig. 1). These precipitation differences were associated with elevation and storm patterns, which move onto the watershed from the west and southwest. This storm pattern caused high precipitation on the south and west sections of the watershed and precipitation shadows on the north and northeast sections.

Precipitation on the watershed increased with elevation and showed a seasonal pattern, with lowest amounts in July and greatest amounts in December and January (table 2). The location of the four sites listed in table 2 is shown on figure 1. The data in table 2 show that 41 percent of the average annual pre-

Table 2.--*Monthly and annual precipitation at 4 sites on the Reynolds Creek Experimental Watershed, 1962-77*

Month	076X59 (1193 m)			116X91 (1454 m)			155X07 (1649 m)			163X20 (2164 m)		
	Average	High[1]	Low[2]	Average	High[1]	Low[2]	Average	High[1]	Low[2]	Average	High[1]	Low[2]
	-----Millimeters----			*----Millimeters----*			*-----Millimeters----*			*----Millimeters-----*		
January	39	106	9	71	160	18	120	268	27	208	417	69
February	19	43	6	37	66	10	66	125	17	111	254	30
March	23	65	2	44	105	3	73	157	17	118	273	23
April	22	80	3	44	99	10	58	118	8	92	178	19
May	19	44	3	30	63	6	43	86	10	60	162	20
June	37	77	7	43	106	12	50	110	11	62	117	8
July	7	26	0	10	29	0	16	47	0	16	52	0
August	18	101	0	17	77	0	26	106	0	28	142	0
September	12	40	0	19	58	0	25	71	0	31	81	0
October	23	73	5	39	130	9	53	181	11	67	182	24
November	31	60	4	54	101	2	92	179	6	148	302	20
December	33	132	2	63	219	4	102	311	6	166	378	17
Total	283	[3]372	[4]175	470	[3]624	[4]320	724	[3]1044	[4]493	1107	[3]1472	[4]828
Summer total	116			157			213			264		
Winter total	167			313			511			843		

[1] Wettest month of record.
[2] Driest month of record.
[3] Wettest calendar year precipitation of record.
[4] Driest calendar year precipitation of record.

cipitation fell from May through October at the low elevation, 1193 m, station (076X59); whereas, only 24 percent fell during the same period at the high elevation, 2164 m, station (163X20). These percentage differences show that a greater proportion of the annual precipitation fell during the winter at high elevations than at the lower elevations. This can be attributed to the way the winter storms move over the watershed from the west and southwest.

Monthly and annual precipitation at the four sites (table 2) show how precipitation varied by month with elevation. July had the least average precipitation at the four sites, and ranged from 7 mm at 076X59 to 16 mm at 155X07 and 163X20. The greatest average monthly precipitation was during January, and varied from 39 mm at 076X59 to 208 mm at 163x20. In general, July, August, and September were the driest months and November, December, and January were the wettest. June precipitation was greater than May or July precipitation at the four sites. This June maximum at Reynolds Creek Station 076X59 does not show up in the 38-yr (1940-77) record at the Boise airport, where the average monthly precipitation for each month, February through June, ranged from 26 mm to 30 mm and then decreased to 5 mm in July (fig. 3). The 16-yr (1962-77) record at Boise also indicates that during that period May precipitation was below average and June precipitation was above. The low monthly precipitation (table 2) varied from none at least 1 year during July, August, and September at all sites to more than five times the monthly mean during August at site 076X59.

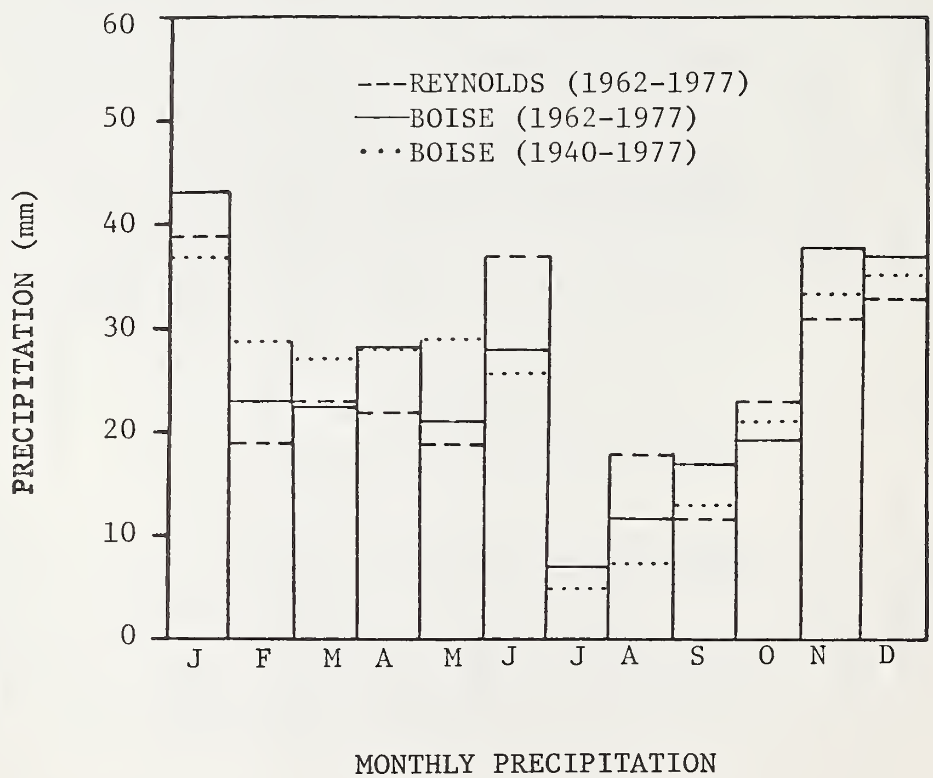

Figure 3.--Monthly precipitation at Reynolds Creek Watershed, site 076x59 and the Boise Weather Service Office, Airport Station, Idaho. Average annual precipitation: 283 mm, Reynolds (1962-77); 296 mm, Boise (1962-77); and 295 mm, Boise (1940-77).

The yearly maximum precipitation varied from 1.31 times the average at 076X59 to 1.44 times the average at 155X07. The year with the least precipitation ranged from 0.62 times the average at 076X59 to 0.75 times the average at 163X20, which shows that there was less yearly variation at the high elevations during this period of record.

Precipitation-Elevation Relationships

Precipitation-elevation relationships are shown in table 3. The regression equations were computed for the west sites, east sites, and all stations (fig. 1). The equations were based on the mean precipitation for 38 stations with the longest records. The information in table 3 shows that the precipitation-elevation relationship depends on season and site location. Precipitation increased less with elevation increase during the summer months than the winter months. This shows that, on the average, summer precipitation is more uniform over the watershed than winter precipitation. Generally, more precipitation fell at the higher elevations than at the low elevations from the winter frontal storms.

Table 3.--*Regression equation Y = a+bX relating precipitation (Y), in millimeters, to elevation (X), in millimeters (a and b are regression coefficients)*
[R^2, coefficient of determination; SE, standard error; N, Number of samples]

Precipitation site	Period considered	Regression coefficients a	Regression coefficients b	R^2	SE	N
All stations	Annual	-513	0.647	0.640	140	38
	November-April	-476	.520	.621	117	38
	May-October	- 36	.127	.672	26	38
East side stations	Annual	-203	.372	.585	101	14
	November-April	-219	.294	.549	86	14
	May-October	15	.078	.680	17	14
West side stations	Annual	-652	.772	.806	105	24
	November-April	-598	.625	.778	92	24
	May-October	- 54	.147	.863	16	24

In general, the east side of the watershed received less precipitation than the west side. This was because the greatest precipitation-producing storms moved over the watershed from the southwest to northwest, and the highest mountains on the watershed are along the south and southwest side of the watershed. The precipitation-elevation relationships for the west side of the watershed were higher than those on the east side as indicated by the coefficient of determination (R^2). This would indicate that the mean precipitation is not as uniformly distributed on the east side as on the west. This does not indicate

the effect of summer thunderstorms, which often did not cover large areas. The local thunderstorm phenomenon was especially prevalent at the lower elevations at the north end of the watershed.

Storm Duration

Many hydrologic and engineering investigations require a knowledge of precipitation characteristics, such as storm duration and time between storms. Sites 076X59 and 163X20 were selected for these investigations because they are located in the low and high elevation precipitation regimes.

The numbers of storms during the December-January and July-August 2-month period were considered indicators of the precipitation regimes at both sites. There were 104 storms during July and August for the 16 years at 076X59, and 139 at 163X20, which correspond with the greater average July and August precipitation at 163X20 (table 4). Precipitation per storm averaged 4 mm at 076X59 and 5 mm at 163X20. At 076X59, there were 14 storms with durations of 15 min or less and 44 storms that lasted less than 1 hr. There were more storms in these two categories at 163X20, but they accounted for approximately the same percentage of the total number of storms. One storm at 076X59 and four storms at 163X20 lasted more than 1 day. The longest storm at 163X20 was 43 hr.

As can be seen from figure 4, the July-August cumulative frequency curves for both sites are the same for storms of 5 hr duration and greater. These storms account for approximately 20 percent of the storms. These analyses show that the summer storm durations were similar at the two sites.

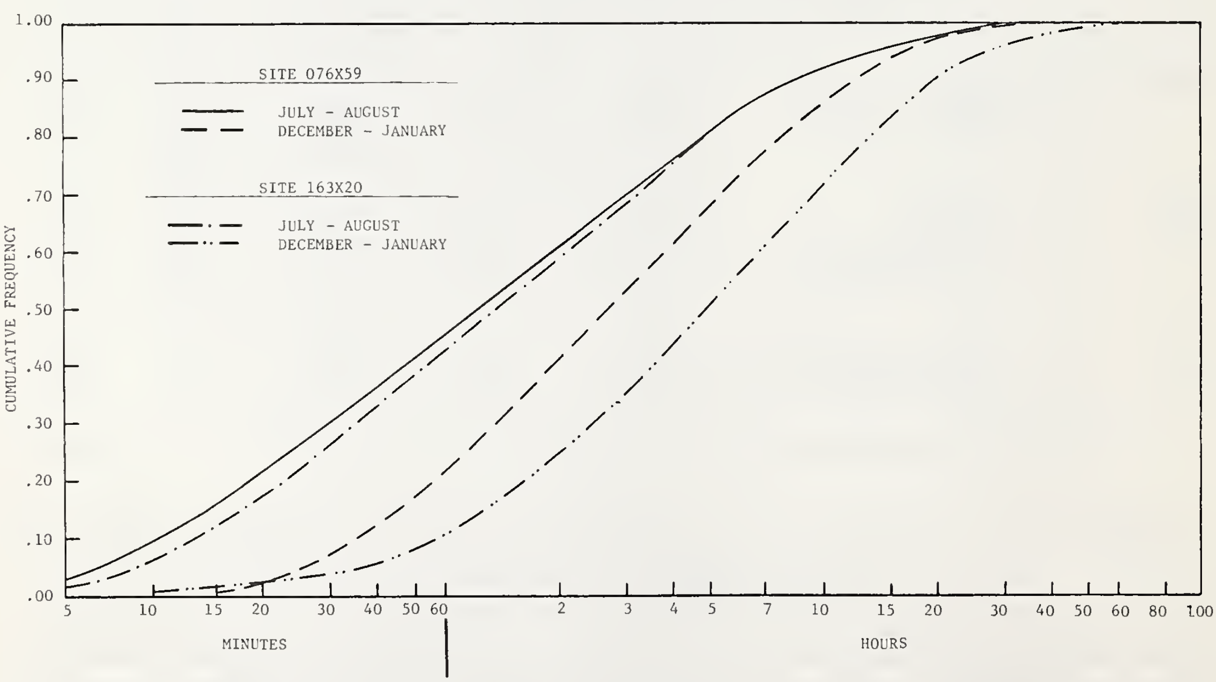

Figure 4.--Duration of storms during July-August and December-January at sites 076X59 and 163X20.

Table 4.--*Frequency of storm durations*

Time		Precipitation site			
		December-January		July-August	
Hours	Minutes	076X59	163X20	076X59	163X20
	5	0	1	3	3
	10	0	3	3	6
	15	3	3	8	9
	20	7	5	11	9
	30	12	7	12	12
	40	16	11	4	8
	50	15	5	3	6
1	0	32	30	8	9
1	30	31	34	7	10
2	0	20	25	6	9
2	30	13	24	5	8
3	0	22	28	3	6
3	30		21	2	5
4	0	30	27	5	5
5		22	29	2	9
6		20	28	5	5
7		14	22	2	2
8		13	22	5	4
9		5	15	2	2
10		4	21	0	2
11-20		39	92	7	6
21-30		9	28	1	2
31-40		0	10	0	1
41		1	8	0	1
Total storms		328	499	104	139
Mean.....hours....		5.2	8.6	3.4	3.9
Median...hour(s)..		3.0	5.0	1.0	1.5

During December and January, there were 328 and 499 storms at 076X59 and 163X20, respectively. Precipitation per storm averaged 4 mm at 076X59 and 12 mm at 163X20 during this period. Precipitation per storm was approximately the same at site 076X59 for both the summer and winter conditions. At site 163X20, however, the winter storms had more than twice the precipitation per storm during the summer.

Approximately 50 percent of the storm durations at the high elevation site, 163X20, were 1 hr or less during July-August, 5 hr or less in December-January.

Similarly, 50 percent of the storm durations at the low elevation site, 076X59, were also 1 hr or less in July-August, but only about 3 hr or less in December-January, showing that summer storms were of approximately equal duration at high and low elevations, but that winter storms had much longer durations at the high elevations than at the low elevations.

During December and January, 7 percent of the storm durations were shorter than 1 hr at 163X20 and 16 percent at 076X59, another indication that winter storms had longer durations at 163X20 than at 076X59. At 076X59, there were five storms that lasted more than 24 hr, and the longest storm lasted 41 hr. At 163X20, there were 31 storms that lasted more than 24 hr and three that lasted more than 48 hr--one of which lasted 83 hr. As shown in figure 4, at 076X59, 50 percent of the storms were less than 3 hr in duration; whereas, 50 percent of the storms at 163X20 were less than 5 hr in duration.

Interval Between Storms

The interval between storms for sites 076X59 and 163X20 is shown on figure 5. As with storm durations, the July-August interval between storms was about the same at both sites. Data in table 5 show that 50 percent of the intervals were about 1.7 days or less. The maximum interval between summer storms was 57 days at 076X59 and 63 days at 163X20. At both sites, approximately 40 percent of the intervals were 1 day or less, which indicated that, during the summer, some days experienced more than one storm.

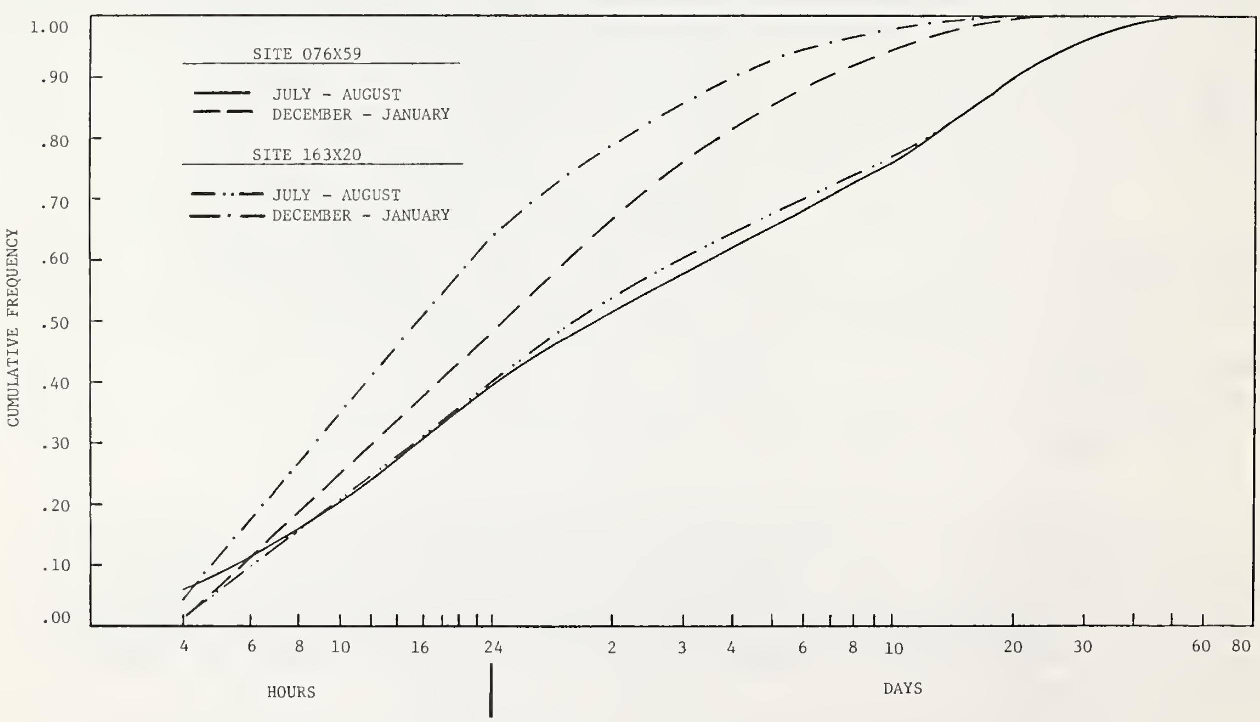

Figure 5.--Interval between storms during July-August and December-January at sites 076X59 and 163X20.

Table 5.--*Frequency of intervals between storms*

Time		Precipitation site			
		December-January		July-August	
Hours	Days	076X59	163X20	076X59	163X20
4-8		73	143	15	23
9-13		31	73	12	12
14-18		22	49	5	7
19-24		38	63	14	17
	1.5	29	38	3	12
	2	31	38	5	9
	3	24	31	8	3
	4	22	19	2	8
	5	11	9	1	2
	6	9	13	4	5
	7	5	5	5	3
	8	4	3	3	1
	9	5	2	2	2
	10	2	3	2	5
	11-15	17	6	6	7
	16-20	2	3	6	12
	21≤	3	1	11	11
Total intervals		328	499	104	139
Mean.....days....		2.9	1.7	7.7	6.6
Median...day(s)..		1.0	0.7	2.0	1.5

As would be expected, the time between storms during the winter was less than during the summer. The cumulative frequency curves for the two sites were very different during the winter months, which reflects different conditions than those occurring during the summer months when the two curves were almost the same. At 076X59, 50 percent of the intervals were 1 day or less; and at 163X20, 50 percent were 15 hr or less. These data show that at both sites there are many days when more than one storm occurred during the same day. The longest period between winter storms was 42 days at 076X59 and 24 days at 163X20. The data indicate that most of the dry intervals were 20 days or less at 076X59 and 17 days or less at 163X20.

Two-yr 6-hr Precipitation

The Universal Soil Loss Equation (USLE) is being adapted to western U.S. rangeland conditions (*9*, *12*). One of the parameters in the USLE is the 2-yr 6-hr precipitation in inches. For most erosion studies, the 2-yr 6-hr precip-

itation values are obtained from the "Precipitation Frequency Atlas of the Western United States" (*8*). The following analyses were done to determine how well the figures in the atlas represented the precipitation frequency conditions found on Reynolds Creek Experimental Watershed.

Partial duration frequencies for the 21 sites with 15- or 16-yr records were determined from annual series data according to the procedures outlined in the atlases (7, *8*) and by Haan (2). The values obtained from the analyses were plotted on the isopluvial map (fig. 6). As can be seen, the 2-yr 6-hr values are about 20 mm at the lower elevation areas on the northern and eastern sides of the watershed. The values generally increase with increasing elevation, with the maximum value of 40 mm at the 2000 m elevation on the south and west sides of the watershed. The relationship between the 2-yr 6-hr values and elevation is shown in figure 7. The regression relationship between the 2-yr 6-hr values and elevation is:

$$Y = -0.40 + 0.018X \quad (R^2 = 0.69) \qquad (2)$$

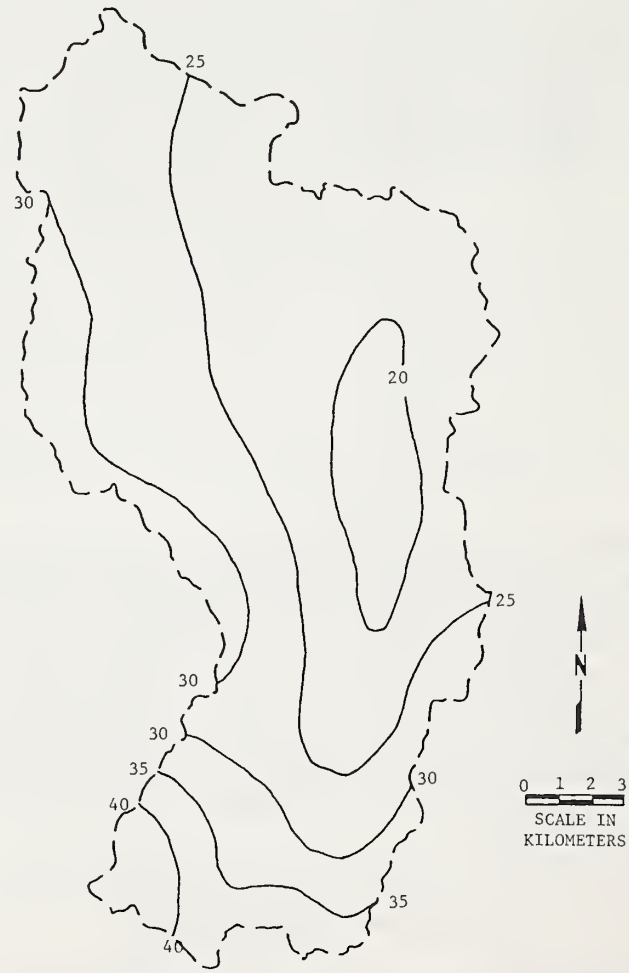

Figure 6.--Isopluvials of 2-yr 6-hr precipitation, in millimeters, Reynolds Creek Experimental Watershed.

where, Y is the 2-yr 6-hr precipitation in millimeters, and X is the elevation expressed in meters. As mentioned before, the direction of storm travel, source of water, and location of the mountains affected the precipitation distribution on the watershed. This can be seen in this analysis, because the higher precipitation values were located on the southwest section, and the lower values were located on the north and east sections of the watershed in the rain shadow. One of the reasons for the variability in the data was that more precipitation fell on the southwest side than on the east side of the watershed at the same elevations.

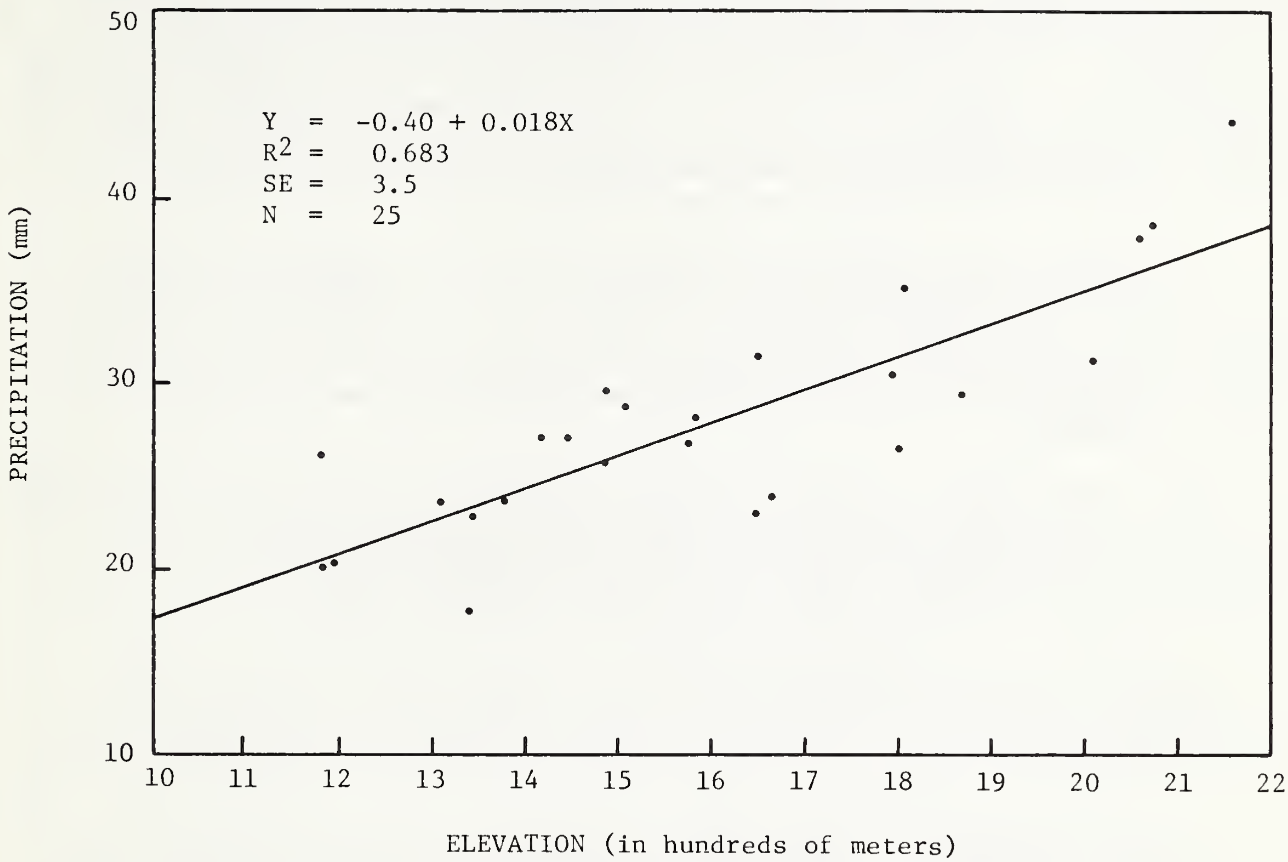

Figure 7.--Relationship between 2-yr 6-hr precipitation and elevation.

The maximum annual 6-hr precipitation amount occurred during the summer in six of the 16 yr at 076X59 and in only two of the 16 yr at 163X20. This indicates that the summer thunderstorms contribute a significant number of the maximum precipitation events at the lower elevation; whereas, at the high elevation, winter storms, generally, are the cause of the greatest 6-hr precipitation. The precipitation frequency atlas (*8*) shows a 2-yr 6-yr frequency value of 20 mm for the watershed area. This is a good estimate at the lower elevations, but does not represent the elevations above 1600 m. As shown in figure 6, the atlas should contain frequency values of 40 mm or more at the higher elevations of this mountain range, if the USLE is to be accurately used.

DISCUSSION

Data from the network were analyzed to determine: (1) Average monthly and annual precipitation; (2) precipitation-elevation relationships; (3) storm duration; (4) interval between storms; and (5) 2-yr 6-hr precipitation. Average annual precipitation varied from less than 300 mm on the low elevation (1100 m) of the northeastern area to more than 1100 mm on the high elevation (2150 m) of the southwestern area of the watershed.

The precipitation-elevation analyses showed a good relationship between annual and seasonal, May through October and November through April, precipitation and elevation. The precipitation-elevation relationship was improved by analyzing the west and east side sites separately. The precipitation-elevation relationships for the summer (May-October) were almost the same for the west and east sites. The relationship during the winter (November-April), however, was different because the major winter storms travel across the watershed from a westerly direction, and, thus, the high elevations on the south and west sides of the watershed received the most precipitation.

The average storm duration varied only from 3.4 hr at the low elevation site to 3.9 hr at the high elevation site during July and August. This variation between sites during December and January was considerably more when the average storm duration was 5.2 hr at low elevations and 8.6 hr at high elevations. The winter storms at both the low and high elevations were longer than during the summer.

The interval between storms averaged 7.7 days at the low elevation site and 6.6 days at the high elevation site during July and August. During December and January, the average interval between storms was 2.9 days at the low and 1.7 days at the high elevation sites. The interval between winter storms at both the low and high elevations was less than during July and August.

The 2-yr 6-hr precipitation at the low elevations on the watershed was about 20 mm, which was the value shown in the precipitation frequency atlas (*8*) for the Owyhee Mountains. The 2-yr 6-hr precipitation at the higher elevations on the watershed was about 40 mm, which is twice the value in the atlas.

These analyses show precipitation characteristics of a mountainous area from a dense precipitation gage network and provide data for hydrologic modeling and resource inventory evaluation. The results also show precipitation-elevation relationships and durations for representative summer and winter storms that were previously not available from weather records. For erosion studies, where an index of storm intensity is needed, the 2-yr 6-hr data also provide much greater detail than that which was previously available.

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